

09/706,737
YO920000549US1
YOR.241

2

AMENDMENTS TO THE CLAIMS:

1. (Currently Amended) In a computer system where forecasting of computing resources is performed based on past and present observations of measurements related to said resources, a computer-implemented method for preprocessing including decomposing said past and present observations into a smooth time sequence, a jump time sequence, a noise time sequence and a spike time sequence, the computer-implemented method comprising:

detecting the spikes in a signal representing said measurements;
detecting the jumps in said signal;
removing spikes and jumps from said signal; and
removing the noise from the signal, to obtain a smooth version of the signal, thereby to provide a basis for said forecasting of said computing resources by said computer system; and
providing, by said computer system, said forecast based on said smooth version of the signal.

2. (Original) The method of claim 1, wherein the removing of the noise comprises:

estimating the variance of the noise.

3. (Original) The method of claim 2, further comprising:

estimating the variance of the noise prior to said detecting of said spikes.

4. (Original) The method of claim 1, further comprising:

09/706,737
YO920000549US1
YOR.241

3

estimating the variance of the noise prior to said detecting of said spikes.

5. (Original) The method of claim 1, wherein estimates of the quantities necessary to decompose the sequence are performed by first applying an invertible transform to the data associated with said observations.

6. (Original) The method of claim 5, wherein said transform comprises a discrete wavelet transform (DWT).

7. (Original) The method of claim 5, wherein said transform comprises a discrete fast Fourier transform.

8. (Original) The method of claim 6, further comprising estimating a variance of the noise using the coefficients of a highest frequency subband of the wavelet transform.

9. (Original) The method of claim 8, wherein the spikes are detected as up-and-down and down-and-up local variations, said spikes being judged not to be noise based on a result of a statistical test based on said estimating of the noise variance.

10. (Original) The method of claim 1, wherein said forecasting is for capacity management.

11. (Original) The method of claim 1, wherein said forecasting is for software rejuvenation.

09/706,737
YO920000549US1
YOR.241

4

12. (Original) The method of claim 1, wherein said forecasting is performed by estimating a trend of the smooth time sequence.

13. (Original) The method of claim 1, wherein seasonal components are removed from the smooth time sequence.

14. (Original) The method of claim 1, wherein seasonal components are separately removed from the smooth time sequence, the noise sequence, the spike sequence and the jump sequence.

15. (Original) The method of claim 1, wherein said forecasting is performed on each of said smooth time sequence, said jump time sequence, said noise time sequence, and said spike time sequence

16. (Original) The method of claim 1, wherein said forecasting is performed on statistics of the jump time sequence, the noise time sequence and the spike time sequence.

17. (Original) The method of claim 1, wherein preprocessed data is based on the smooth version of the signal input to a forecasting algorithm for analyzing the preprocessed data, to produce a prediction.

09/706,737
YO920000549US1
YOR.241

5

18. (Original) The method of claim 1, wherein the signal is denoted by x , its value at time i by $x(i)$, a sequence of values by $\{x(t)\}$, and a part of a sequence between times i and k by $\{x(i), \dots, x(k)\}$, and

wherein the noise represents unpredictable localized variations of the signal and is denoted by z , the spikes represent unpredictable localized up-and-down or down-and-up variations not judged to be noise, denoted by p , and the jumps are a zero-mean component, which is a piecewise constant other than at discontinuity points where the signal changes either upwards or downwards, but not in both directions, denoted by j , and the smooth time sequence is a difference between the signal and a sum of noise, spikes and jumps, denoted by y such that

$$\{x(t)\} = \{z(t) + p(t) + j(t) + y(t)\}.$$

19. (Original) The method of claim 2, wherein the estimating of the variance of the noise includes:

computing a Discrete Wavelet Transform (DWT) of the signal;

extracting from the DWT a predetermined frequency subband depending upon a format of the DWT; and

producing an initial noise variance based on said predetermined frequency subband.

20. (Original) The method of claim 19, further comprising correcting an initial estimate of the variance using the spike and the jump series extracted during a previous decomposition.

21. (Original) The method of claim 1, wherein said removing of said spikes comprises:

09/706,737
YO920000549US1
YOR.241

6

producing a Discrete Wavelet Transform (DWT) of the signal;
extracting a predetermined frequency band of the DWT; and
identifying candidate locations of spikes based on a predetermined frequency band and a noise variance estimate.

22. (Original) The method of claim 21, wherein the identifying of candidate locations includes thresholding the predetermined frequency band with a threshold that depends on the estimate of the noise variance, such that each element of the predetermined frequency band having an absolute value larger than the threshold is declared a candidate location, and

wherein the threshold is selected to discard the noise and to retain values not statistically defined by a noise process.

23. (Original) The method of claim 21, further comprising:

identifying actual individual spikes, wherein said identifying actual individual spikes comprises:

taking as inputs the signal and the estimated variance of the noise; and

letting subscript i denote a location of a candidate spike and assuming that a spike of width w at location i is a sequence of $(w + 1)$ samples, x_{i-1} , x_i , x_{i+1} , such that a difference $d_1 = (x_{i-1} - x_{i+1})$ is a sum variation in a smooth signal plus additive noise, and that the absolute value of a difference $d_2 = [x_i - (x_{i-1} + x_{i+1})/2]$ is too large to be explained by a same model, computing the differences d_1 and d_2 , and comparing the two differences to two thresholds T_1 and T_2 ,

09/706,737
YO920000549US1
YOR.241

7

wherein if an absolute value of d_1 is less than T_1 and the absolute value of d_2 is larger than T_2 , then the candidate spike is declared to be a spike.

24. (Original) The method of claim 1, wherein said detecting of said jumps comprises:

computing a Discrete Wavelet Transform (DWT) of the signal and producing a sequence of details obtained while computing the DWT, such that the details have a same length as the signal, wherein a collection of first k details plus the signal forms a $(k+1)$ -level multi-resolution pyramid;

iterating over the $(k+1)$ levels of the pyramid, such that at each said level a windowed linear regression is computed to produce a time series of slopes, wherein a time series of slopes is computed for the signal and a time series of slopes is computed for each of the details, such that in total $(k+1)$ time series are produced,

wherein said windowed linear regression uses a sliding window of width w , which takes as an input a time series $\{x(1), \dots, x(n)\}$ and produces $n-w+1$ subseries $\{x(1), \dots, x(w)\}$, $\{x(2), \dots, x(w+1)\}, \dots, \{x(n-w+1), \dots, x(n)\}$ and a linear regression is computed for each of the subseries, by fitting a straight line segment to the data using a least squares criterion, and a slope sequence $\{s(1), \dots, s(n-w+1)\}$ is generated.

25. (Original) The method of claim 24, wherein by applying windowing and segment fitting to each of the details a $k+1$ slope series of length $n-w+1$ is generated,

said detecting of the jumps further comprising:

09/706,737
YO920000549US1
YOR.241

8

after all of the slope series are computed, computing a product of the slopes, wherein the jumps appear as extrema of the slopes at all the levels of the multi-resolution pyramid;
extracting local extrema and producing a list of candidate jump locations; and
removing extrema having a predetermined small absolute value and retaining extrema with a predetermined large absolute value, which are declared jumps.

26. (Original) The method of claim 1, wherein said noise removal comprises:

subtracting the spike series and the jump series from the signal, thereby producing a sequence which contains a sum of the smooth signal and the noise sequence;

based on the sequence, estimating a variance of the noise;

computing the energy of the sequence, by computing a sum of the squares of the values;

removing the noise from the sequence, and using the estimate of the noise variance by computing a wavelet transform of the sequence, wherein coefficients of the transform are soft-thresholded using a threshold T based on the estimate of the noise variance, and

wherein the soft-thresholding with threshold T applied to a value x is the operator $S(x, T)$ defined as:

$$\begin{aligned} S(x, T) &= x - T && \text{if } x > T, \\ S(x, T) &= x + T && \text{if } x < -T, \\ S(x, T) &= 0 && \text{otherwise,} \end{aligned} \tag{1}$$

09/706,737
YO920000549US1
YOR.241

9

wherein the operation (1) is applied to all values of the residual and detail sequences of the transform, and a thresholded signal is obtained;

restoring the energy by taking as inputs the thresholded signal and the energy of the signal, and dividing the energy by the energy of the thresholded signal, taking the square root, and multiplying the result by the thresholded signal, to produce the smooth signal having a same energy as a signal having the smooth and noise components; and

obtaining the noise by subtracting the smooth signal from the signal having the smooth and noise components.

27. (Original) The method of claim 1, where at least one of said computing resources is exhaustible.

28. (Currently Amended) A computer system, comprising:

a forecast module for forecasting computing resources based on observations of measurements related to said resources; and

a data preprocessing module for decomposing said observations into a smooth time sequence, a jump time sequence, a noise time sequence and a spike time sequence, wherein said data preprocessing module comprises:

an estimator for estimating a variance of the noise;

a detector for detecting the spikes and jumps in said estimated variance of the noise;

a subtractor for subtracting spikes and jumps from the signal, said estimator further estimating the variance of the noise of said signal based on said spikes and jumps having been

09/706,737
YO920000549US1
YOR.241

10

removed, and said subtractor removing the noise, to obtain a smooth version of the signal, for input to said forecasting module to provide a basis for said forecasting of said computing resources by said forecasting module,

wherein said forecasting module provides said forecasting based on said smooth version of the signal.

29. (Currently Amended) A signal-bearing medium tangibly embodying a program of machine-readable instructions executable by a digital processing apparatus to perform a computer-implemented method for preprocessing data to be used for forecasting of computing resources based on observations of measurements related to said resources, said computer-implemented method for preprocessing including:

decomposing said observations into a smooth time sequence, a jump time sequence, a noise time sequence and a spike time sequence, said decomposing comprising:

detecting the spikes in a signal representing said measurements;

detecting the jumps in said signal;

removing spikes and jumps from said signal; ~~and~~

removing the noise from the signal, to obtain a smooth version of the signal, thereby to provide a basis for said forecasting of said computing resources by said digital data processing apparatus ; and

providing, by said digital data processing apparatus, said forecast based on said smooth version of the signal.

09/706,737
YO920000549US1
YOR.241

11

30. (Currently Amended) In a computer system where forecasting of computing resources is performed based on past and present observations of measurements related to said resources, a computer-implemented method for preprocessing including decomposing said past and present observations into a smooth time sequence, a jump time sequence, a noise time sequence and a spike time sequence, the computer-implemented method comprising:

detecting the spikes in a signal representing said measurements;

detecting the jumps in said signal;

removing spikes and jumps from said signal; and

removing the noise from the signal, to obtain a smooth version of the signal, thereby to provide a basis for said forecasting of said computing resources by said computer system; and providing, by said computer system, said forecast based on said smooth version of the signal,

wherein at least one of said computing resources is exhaustible, and wherein the removing of the noise comprises:

estimating the variance of the noise prior to said detecting of said spikes,

wherein estimates of the quantities necessary to decompose the sequence are performed by first applying an invertible transform to the data associated with said observations and wherein said transform comprises a discrete wavelet transform (DWT),

wherein the estimating the variance comprises estimating a variance of the noise using the coefficients of a highest frequency subband of the wavelet transform, and wherein the spikes are detected as up-and-down and down-and-up local variations, said spikes being judged not to be noise based on a result of a statistical test based on said estimating of the noise variance,

09/706,737
YO920000549US1
YOR.241

12

wherein said forecasting is performed by estimating a trend of the smooth time sequence, and
wherein seasonal components are separately removed from the smooth time sequence, the
noise sequence, the spike sequence and the jump sequence, and wherein said forecasting is
performed on each of said smooth time sequence, said jump time sequence, said noise time
sequence, and said spike time sequence.